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The Use of Sawdust for Mulches and Soil Improvement

Circular No. 891

November 1951 • Washington, D. C.

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The Use of Sawdust for Mulches and Soil Improvement

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INTRODUCTION

LARGE QUANTITIES of sawdust and other wood wastes accumulate in this country each year, especially in the far West, North Central, and Southern States. Much of this sawdust and other discarded material is destroyed by burning, or is allowed to remain unused where it accumulates (fig. 1). If these wastes were properly utilized, they could under many conditions be of considerable value to agriculture. Most of our soils are greatly in need of organic matter because the usual crop rotations seldom maintain soil humus [1] at as high a level as desirable. Wood waste constitutes additional plant residues that should be utilized for humus maintenance in every location where it is economically feasible to do so.

Some of the main facts regarding the use of sawdust for soil improvement are presented in this circular. Although the emphasis is

[1] The term "humus" is used to designate all well-decomposed, ever-varying, organic matter that has largely lost its original structure, and not merely the alkali-soluble portion that is often designated by chemists as humus. It consists of a complex mixture of the remnants of plant materials and viable and dead soil micro-organisms and their synthetic products.

FIGURE 1.—Sawdust frequently presents a disposal problem: A heap covering an area of about 4 acres (top), and slow burning of a small heap (bottom).

on sawdust, this material differs little from other wood wastes such as chips, shavings, and bark, except that decomposition is more rapid in the more finely divided materials, and the absorbing power, when sawdust is used as a bedding, is higher.

Wood chips deserve special mention even though the quantity produced is small. Chipping machines are now available commercially

and they are being used to an increasing extent as a convenient means for disposing of tree prunings. The chips may sometimes be obtained at little or no cost. Since the percentage of bark, buds, and leaves present in tree-pruning chips is often high, the nutrient content is likely to be a little higher than that of sawdust. These chips constitute an excellent mulching material that is considerably coarser than sawdust, is less likely to cake, and usually decomposes more slowly. Production and utilization of chips are illustrated in figure 2.

Figure 2.—The production and use of wood chips: *A*, Chips are often produced on a city street as shade trees are trimmed; *B*, though sizes vary, all are suitable for use as a mulch; and *C*, blueberries mulched with chips make good growth; black material soon forms beneath the surface.

COMPOSITION OF SAWDUST

The average plant-nutrient content of sawdust in comparison with wheat straw and alfalfa hay is given in table 1. It will be observed that sawdust is extremely low in nitrogen and in the ash constituents that are of primary importance in crop production. Because of this, undecomposed sawdust would seldom be worth the cost of hauling if its only value were to supply mineral nutrients.

TABLE 1.—*Quantities of the principal plant nutrients contained in various plant products, per ton of dry matter*

Dry material	Nitrogen (N)	Phosphorus (P_2O_5)	Potash (K_2O)	Lime (CaO)	Magnesium (MgO)
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Sawdust	4	2	4	6	0.5
Wheat straw	10	3	12	4	1.2
Alfalfa hay	48	10	28	28	7.0

On burning, sawdust leaves only a small amount of residue, provided no charcoal remains. Although the quantity is small, analysis shows that this ash is fairly rich in plant nutrients, especially potash. The content of the more important minerals found in the ash of some of our common woods, as reported by White (*27*, *28*),[2] is shown in table 2. Since ordinary wood ashes as obtained in the home fireplace commonly contain considerable sand and charcoal, the percentage of such minerals is considerably lower. Any leaching, of course, lowers the nutrient content still further. Lunt (*11*) gives a good discussion of these points and the probable value to the farmer of wood ashes of various kinds. Wood ashes constitute a valuable source of minerals for crop use and also act as a partial substitute for lime. They should be carefully conserved and utilized.

TABLE 2.—*Percentage of certain nutrients in some wood ashes*

Species	Ash [1]	Potash (K_2O)	Sodium (Na_2O)	Lime (CaO)	Magnesium (MgO)	Phosphorus (P_2O_5)	Sulfur (SO_3)
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Red oak (*Quercus rubra*)	0.85	16.4	3.7	32.3	3.6	7.0	2.3
White oak (*Quercus alba*)	.37	29.9	1.9	21.2	2.4	6.7	4.1
White ash (*Fraxinus americana*)	.43	34.7	.9	17.7	.5	2.7	8.6
Sycamore (*Platanus occidentalis*)	.99	18.2	5.9	25.0	.5	9.7	5.7
Shortleaf pine (*Pinus mitis*)	.35	13.0	1.2	43.3	2.1	2.8	.9
Longleaf pine (*Pinus palustris*)	.49	10.3	2.3	37.2	4.2	2.7	4.3

[1] In wood containing 10 percent moisture.

[2] Italic numbers in parentheses refer to Literature cited, p. 17.

Sawdust consists chiefly of organic materials synthesized by the tree from water, and from carbon dioxide and oxygen of the air. The ultimate composition (*22*) in terms of the elements does not differ markedly for various woods. The variations are approximately as follows: Carbon 48 to 54 percent, hydrogen 5.8 to 6.3, oxygen 39 to 45 and nitrogen 0.1 to 0.6. The nitrogen percentage rarely is as high as 0.6 percent; it usually varies between 0.1 and 0.3 percent.

The principal organic constituents of wood that are of agricultural interest are cellulose, lignin, and pentosans. Table 3 gives the percentages of these constituents in several common woods, as reported by Schorger (*22*). When added to soil, the cellulose and pentosans are attacked most rapidly by micro-organisms. Lignin and lignin-degradation products, along with the residues of micro-organisms, tend to remain as constituents of humus. All of the three organic compounds listed in table 3 contribute to humus formation but, per unit weight, lignin is considered to be the most important.

IS SAWDUST TOXIC TO PLANTS?

When undecomposed sawdust or other wood products are applied singly to soils and a crop is planted immediately, the yields are almost invariably decreased. This fact is well known and many farmers hesitate to apply the material. They often consider it toxic. The decrease in crop yields produced by undecomposed sawdust is discussed under the following headings: (a) Toxic constituents, (b) increase in soil acidity, and (c) depletion of available soil nitrogen.

TABLE 3.—*Percentage of the principal organic constituents of agricultural interest in sawdust of some wood species*

Wood	Cellulose	Lignin	Pentosans
	Percent	*Percent*	*Percent*
Western yellow pine	57. 4	26. 7	7. 4
Spruce	57. 8	28. 3	11. 3
Tanbark oak	58. 0	24. 9	19. 6
Hickory	56. 2	23. 4	18. 8
Beech	53. 5	22. 5	24. 9
Birch	45. 3	19. 6	27. 1
Poplar	47. 1	18. 2	23. 8

Toxic Constituents

Present evidence seems to show that occasionally small amounts of compounds that are toxic to plants may be present in a few woods (*2*, *6*). This is exceptional, and most sawdust and other wood wastes contain no appreciable amounts of such compounds. Gibbs and Batchelor (*4*) noted in laboratory studies that sawdusts of ash, larch, maple, white pine, yellow pine, white fir, and red fir had little or no harmful effect on soil nitrogen-fixing bacteria; but cedar showed some retardation. Material from leaves and needles of some of these trees was somewhat inhibiting. Among the constituents usually mentioned as possibly toxic are tannins, resins, and turpentine (*8*).

Recent studies tend to show, however, that when these constituents are present in woods in the usual concentrations they are not appreciably toxic, if at all. Any toxicity that may exist initially disappears within a few weeks after addition to soil, because the toxic substances are destroyed by soil bacteria and fungi that are always present.

Almost all workers (*1, 10, 12, 15, 16, 17, 19, 23, 24, 26*) who have used sawdust or other wood products, regardless of the rate of application, have observed no toxicity if the materials were used in conjunction with adequate nitrogen.

Increase in Soil Acidity

Most kinds of sawdust obtained from the sawmill are slightly acid, as shown by McCool (*13*). He observed that sawdust from cypress is the most acid (pH 3.5 to 3.9); sawdusts from yellow pine, spruce, white oak, black oak, and redwood are less acid (pH 4.1 to 5.0); those from blue beech, larch, red oak, white birch, sugar pine, maple, pin oak, Japanese larch, and red pine are only mildly acid (pH 5.1 to 6.0); and those from locust, elm, and hemlock are nearly neutral (pH 6.1 to 7.0). When these sawdusts were incubated in moist soil or sand for a year the pH changes were usually not marked, but this depended somewhat upon the initial reaction of the soil and the kind of sawdust used.

When sawdust is applied to a lime-requiring crop, any acid in it may be slightly harmful if the soil is already near the lower limit of acidity tolerated by the crop. Otherwise the acid is of minor importance. When applied to acid-requiring plants such as blueberries and azaleas, the acidity, if any, is beneficial. As sawdust decomposes there may be a slight temporary increase in acidity due to the formation of organic acids, but these soon decompose and the final effect on soil reaction is negligible (*12, 13, 20, 23, 25*). Since the ash of plants contains more basic than acidic constituents, the ultimate effect should be toward a slight decrease rather than an increase in acidity. Regardless of this fact, it is usually advisable to add a little lime with the sawdust if the soil is not already well supplied with it.

Depletion of Available Soil Nitrogen

The chief reason for the commonly observed harmful effect on crop yields when sawdust is applied alone is its property of depleting available soil nitrogen, including both ammonia and nitrates. Nitrates normally are continually forming in the soil at a slow rate, and in the absence of a crop will tend to accumulate. Only traces of nitrates may be found in the presence of sawdust, as Viljoen and Fred (*26*), Gibbs and Werkman (*5*), Turk (*24*), and many others have shown. This is well illustrated by the data in table 4, obtained by Viljoen and Fred. Gibbs and Werkman also made extensive studies of this phenomenon, using various tree products.

Cedar, maple, larch, ash, and red fir sawdusts produced the greatest inhibitions of nitrate formation. The needles of white fir, yellow pine, and cedar also caused marked reductions in nitrates. The same effect was obtained with the litter covering the forest floor. The addition of calcium carbonate did not overcome the depressing effect

of the various wood wastes on nitrate formation or accumulation. This apparent toxicity can be avoided by the application of adequate nitrogen, as has been shown repeatedly (*7*, *12*, *16*, *19*, *23*, *24*).

TABLE 4.—*Effect of sawdust on the nitrate content of soil and on the growth of oats during a period of 9 weeks* [1]

Treatment [2]	Nitrate-nitrogen per 100 gm. of soil	Dry weight of plants
	Milligrams	*Grams*
Untreated	2. 13	5. 2
80 gm. sawdust	0	3. 2
16 gm. lime	5. 65	8. 0
16 gm. lime, 80 gm. sawdust	0	3. 6
80 gm. manure	2. 73	8. 5
80 gm. manure, 80 gm. sawdust	0	4. 2
16 gm. lime, 80 gm. manure	8. 62	10. 5
16 gm. lime, 80 gm. manure, 80 gm. sawdust	0	4. 8

[1] See (*26*).
[2] 8 kilograms of soil in each jar.

WHAT HAPPENS WHEN SAWDUST IS ADDED TO SOIL

When undecomposed sawdust is mixed with soil under favorable conditions of temperature and moisture, it immediately starts to decompose just as do other plant materials. The decomposition is brought about by many species of bacteria and fungi. These micro-organisms require a source of energy, which the sawdust supplies, and a source of available nitrogen, which the sawdust does not supply in more than traces. The bacteria and fungi, therefore, obtain it from the only available source—the soil. If a growing crop is present, micro-organisms compete with it for the available supply of nitrogen and unless the soil is exceedingly well supplied with this element, or a supplementary addition is made in a form such as legume green manure or nitrogenous fertilizer, the crop will show nitrogen deficiency.

In this respect most undecomposed sawdusts behave much like other carbonaceous materials such as wheat straw and cornstalks, except that sawdust is even more deficient in nitrogen than are most crop residues. There are also differences in the rates of decomposition of these various materials. Sawdust usually decomposes more slowly than an equal weight of straw, for instance, and the initial nitrogen-depleting effect is less intense, but of longer duration. This is shown in data in table 6 (p. 13).

The nitrate-depleting effect of sawdust seldom extends much, if any, beyond the first season if the application is less than 3 or 4 tons of dry material per acre and conditions are suitable for decomposition. It should be emphasized, however, that very large applications of certain kinds of wood, especially if supplemental nitrogen is not added, may result in nitrate depression over much longer periods. For in-

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stance. Roberts and Stephenson (*19*) observed that where a 3- or 4-inch layer of alder or fir sawdust[3] was incorporated with soil, the nitrates were deficient for 3 to 4 years. In these experiments, 400 pounds of nitrogen were required the first year to offset the depression caused by the sawdust, 200 pounds the second year for fir sawdust and 100 pounds for the alder sawdust, and a proportionate reduction for each the third year. It was further observed that shredded redwood bark and cedar-tow decomposed so very slowly that there was little depression in nitrates even the first year.

Wood products in the soil do not prevent nitrates from forming, but the organisms active in decomposition consume so much nitrogen that less nitrate accumulates or is available for plant growth. Viljoen and Fred (*26*) demonstrated this by supplying an excess of nitrifiable material (blood meal) to sawdust. This was mixed with soil, which was analyzed for nitrates after 4 weeks. The data in table 5 show that nitrate formation proceeded, but that the total accumulation was reduced by the sawdust. The accumulation decreased as increasing quantities of sawdust were applied.

The rate and completeness of decomposition of a plant product, whether it be sawdust or a general farm-crop residue, is determined primarily by composition and available nitrogen. In the case of fresh, undecomposed plant materials, it has been shown (*18*) that if the nitrogen content is about 1.2 to 1.5 percent, and optimum conditions for biological activity are present, decomposition will proceed at approximately the maximum rate without depleting the supply of available soil nitrogen. If the nitrogen percentage is higher than the 1.2 to 1.5 level, available nitrogen will be released to the growing crop. If the percentage is lower, there is usually not enough nitrogen to meet the needs of the micro-organisms that decompose the plant materials, and the rate of decomposition may be slowed markedly unless the deficit is made up from outside sources such as fertilizers.

TABLE 5.—*The effect of sawdust on the nitrification of blood meal in soil in a period of 4 weeks*

Treatment per 100 gm. of soil		Nitrate-nitrogen per 100 gm. of soil	Treatment per 100 gm. of soil		Nitrate-nitrogen per 100 gm. of soil
Sawdust	Blood meal		Sawdust	Blood meal	
Grams	*Grams*	*Milligrams*	*Grams*	*Grams*	*Milligrams*
----------	----------	[1] 6. 6	0. 50	0. 5	33. 4
----------	0. 5	51. 4	1. 00	. 5	30. 0
0. 25	. 5	42. 9	2. 00	. 5	23. 1

[1] Untreated level.

[3] The weight of a unit volume of sawdust is a variable quantity that depends chiefly upon the degree of compaction and moisture content. A cubic yard of loose material ordinarily weighs about 200 to 300 pounds, exclusive of any moisture present. The usual weight of a bushel, then, is 10 to 15 pounds. On this basis, about 75 tons of dry sawdust per acre would be required to produce a 4-inch layer of loose material. Since sawdust is capable of absorbing water to about 2 to 6 times its own weight, it follows that a cubic yard of thoroughly wet sawdust may weigh 1,000 to 1,500 pounds, but contain only 200 to 300 pounds of dry wood.

There is little quantitative information available on the critical nitrogen percentage of sawdust; but for woods such as poplar, beech, and some species of pine that decompose most rapidly, there is every reason to believe that the nitrogen content must be brought up to approximately the 1.2 to 1.5 percent values if the initial harmful effect on crops is to be avoided. Since sawdust usually contains about 0.2 percent nitrogen, the addition of approximately 24 pounds of nitrogen per ton of dry wood, corresponding to 115 pounds of ammonium sulfate or 72 pounds of ammonium nitrate, would be required. The corresponding requirements for a bushel of loose material would be 0.8 and 0.5 pound, respectively, of the two nitrogenous fertilizers.[4] For very slowly decomposing woods such as cypress, cedar, oak, and redwood, the nitrogen requirements may be somewhat less for the first year, but there might be some further nitrogen needs the second year (*7, 19*).

What ultimately happens to the nitrogen assimilated by the microorganisms that decompose sawdust is a matter of considerable practical concern. Bacteria and fungi have a comparatively short life that varies from a few days, or even hours, to a few weeks. When they die they decompose as did the original plant material. Any nitrogen released may be utilized again and again by other microorganisms in the further decomposition of the sawdust residues until practically all of the available energy supply (primarily cellulose and pentosans) in these residues has been destroyed. When this point is reached, the nitrogen in this decomposed material is gradually released just as that in ordinary soil organic matter. The time required to reach this stage will vary with many factors such as temperature, moisture, percentage of nitrogen added, quantity of sawdust applied, and the intimacy with which it is mixed with the soil.

Even under ideal laboratory conditions the release of available nitrogen from such a decomposing sawdust is not likely to be appreciable in less than 4 to 6 months, and the period is usually considerably longer. Zak and Eisenmenger (*30*), for example, added sawdust from southern pine, white pine, cedar, chestnut, and oak, and also shavings from southern pine, hemlock, and birch to soil in equal portions by weight and then determined nitrates at intervals. In these experiments supplementary nitrogen was supplied to bring the content up to 1 percent. Nitrates began to appear at the end of 14 weeks. Peanut and cacao hulls behaved as did the tree products. When Johnson (*7*) used old pine sawdust in a 3-inch layer as a mulch he found that nitrate depression continued for 2 years. Where incorporated with soil the depression lasted for only one season, and benefits to crops were observed the second year.

A slow release of nitrogen is, under most conditions, an advantage, provided supplemental nitrogen is added as needed. This slow release means that the newly formed humus is fairly stable. This humus is the material that is so beneficial for the improvement of the physical condition of the soil and for its general effect in increasing crop yields. There have not been many experiments to show how much humus is formed from sawdust, but the indications are that reasonably well-rotted sawdust weighs about 15 to 25 percent as much

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[4] Quantities of other nitrogen-containing materials required are given in table 7, p. 17.

as the original sawdust. This is exclusive of any mineral additions such as superphosphate, chemical nitrogen, or lime that may have been made to hasten decomposition. Straw and cornstalks yield similar quantities of residual material.

Aside from available soil-nitrogen deficiencies resulting from sawdust additions, it is likely that phosphate deficiencies may also be brought about in a similar manner under some conditions. Bacteria commonly contain from 2 to 5 percent of phosphorus, and since sawdust is very deficient in this element, it is likely that some of the bacterial requirements may be obtained from the soil. Present information on this subject is too limited to justify definite recommendations. However, at least a small supplemental addition of superphosphate, or similar available phosphate, should be made where wood products are added to soils, unless it is known that a phosphate deficit is not likely to be encountered.

VALUE OF HUMUS PRODUCED FROM SAWDUST

Materials that have a fairly high nitrogen content, such as legumes and manure, are considered the best sources of humus. These materials decompose rapidly, whether in the soil or in the compost pile, to produce excellent products. Other materials, such as straw and cornstalks, also decompose fairly rapidly if adequate nitrogen is supplied. It has been shown repeatedly that artificial manures prepared from straw and similar materials are as valuable as rotted manure if they have been reinforced with chemical fertilizers to give the same nutrient composition.

Very little information is available on the comparative values of artificial manures prepared from sawdust, straw, legumes, and other materials, but there seems to be no reason to doubt that one material is about as good as another if the content of fertilizer elements is the same. This point is very important, for the nutrients are usually not the same. Decomposed legumes and stable manure usually contain a considerable excess of nitrogen over that required to decompose the original materials. Decomposed sawdust is likely to be lower in nitrogen, and if so, a lesser beneficial effect on crop yields would be expected.

Regardless of the type of plant material used as a source of humus, most of the energy materials (sugars, cellulose, pentosans, and some of the lignin) contained in it are utilized by micro-organisms to form new products. These new products consist of living organisms, disintegrated cells, and miscellaneous gums and other synthetic substances. Therefore, the nature of the final product (humus) is determined both by the type of organisms involved and by the initial plant substances.

EFFECTS OF ORGANIC MATTER ON SOIL

Thoroughly decomposed organic matter, regardless of whether it is derived from sawdust or other plant materials, serves various useful purposes. Most of these purposes may be grouped under two general heads: (1) Organic matter is a constant source of available nutrients, and (2) it improves the physical condition of the soil.

The principal nutrients constantly released by well-decomposed

organic matter or humus are nitrogen and phosphorus. The rate of release is roughly proportional to the rate of destruction of the humus. Humus also has an important function in holding minor elements in available form. The slow release of the various elements is primarily dependent upon continued activity of micro-organisms, which are in turn dependent upon organic matter for their growth energy. At the same time the organisms may, through the production of organic acids, increase the availability of the inorganic soil constituents.

Humus is badly needed in many clay soils because it makes cultivation less difficult. It does this by forming an organic coating around clay particles, or forming complexes with them, which decrease the tendency of the soil to bake and crack. Many of our soils have become so sticky as a result of organic-matter depletion that they are now cultivated only with great difficulty, and they erode easily. Water penetration into such soils is greatly favored by humus. Sandy soils are also in need of humus for holding nutrients and water. In these soils, humus serves many of the purposes that clay does in heavier soils.

UTILIZATION OF SAWDUST

Growers in many parts of the United States are looking for reliable directions for the successful use of sawdust. General directions without qualifications are not justified, however, on the basis of present information. Sawdust may be used successfully under certain conditions and not under others. Factors reviewed here should help the grower to decide whether or not his agricultural situation is such that benefits from the use of any form of finely divided wood may be expected.

Four practical ways of utilizing sawdust are: As mulch, as a bedding for livestock, in compost, and by direct application to soil.

Mulches

Sawdust constitutes an excellent mulch (*1, 3, 9, 10, 14, 21, 23, 25*) for apple orchards and blueberries, strawberries, and many other fruits, as well as vegetables and flowers, provided adequate nitrogen (see table 7, p. 17) is supplied to the soil. Most of the mediocre results reported for this material in comparison with other mulching materials can be attributed chiefly to its lower content of the essential fertilizer nutrients, especially nitrogen and phosphorus. It is not uncommon for 300 pounds or more of mulch to be applied to a single apple tree. If the mulch happens to be a crop such as hay, the nutrients added per acre in the hay may add up to a fairly heavy application of fertilizer. These nutrients are released slowly in subsequent months as decay proceeds. In a comparison of sawdust with other materials as a mulch on soil to which no supplementary plant nutrients have been added, plant-growth variations are likely to be caused more by the difference in nutrient content of the various mulch materials added than by physical effects. Sawdust applied as a mulch decomposes just as it does when mixed with the soil, except that the rate of decay is usually considerably less. As sawdust decomposes, available nitrogen is depleted and the mulched crop is likely to show nitrogen deficiency. Undoubtedly one of the main factors tending to limit the use of sawdust as a mulch is the cost of the nitrogen needed to overcome the ef-

fects of large applications. Successful use of sawdust mulch is illustrated in figure 3.

Bedding Material

One of the very best ways to utilize sawdust is as a bedding for livestock (*15, 17, 29, 30*). An excellent discussion of this subject, together with experimental data, is given by Midgley (*15*). Not only

Figure 3.—Sawdust may be used as a mulch in a variety of ways: *A*, An apple tree being mulched with partially decayed sawdust; *B*, varied ornamental plants mulched in a home garden.

does sawdust serve as a good bedding material physically but it acts as a good absorbent for urine. According to the data of Midgley, fine sawdust absorbs considerably more water per unit weight than does chopped hay. By conserving liquid manure the necessity for purchase of commercial nitrogen is lessened. Even apart from the liquid portion, many manures, especially those from chickens, sheep, and to a lesser extent cows, contain more nitrogen than required for their decomposition. This excess can be used to help rot the sawdust, if so desired, but any nitrogen so used will not be immediately available for crop use. Whether such use of this available nitrogen is or is not desirable depends upon how the manure is to be utilized and whether immediate crop benefits are desired. If such immediate results are important then the sawdust-manure mixture will probably have to be supplemented with chemical nitrogen. The water-absorbing capacity of various bedding materials, according to Midgley (*15*) follows:

Bedding material:	*Water absorbed and held per 100 pounds of bedding (pounds)*
Fine pine sawdust	545
Pine shavings	267
Coarse pine sawdust	240
Mature chopped hay	298

Experimental results from the use of sawdust in manures are of interest. Turk (*24*), for example, reported increases in the yield of barley on two soils following the use of cow manure containing sawdust bedding, even when no supplemental chemical nitrogen was used. A portion of his data is given in table 6. Data obtained by White (*29*) show that during a period of 5 months the rate of decomposition of sawdust was somewhat less than that of wheat straw, causing, with one exception, less depression of nitrates. Yields of corn were nearly the same with the two bedding materials. Odland and Knoblauch (*17*) compared sawdust or shavings-manure with straw-manure in a 3-year rotation over an 18-year period and concluded that "no detrimental effects to the land have resulted from the use of shavings or sawdust bedding as compared with straw."

TABLE 6.—*Effect of sawdust on growth of barley in greenhouse*

Soil treatment	Total dry weight per pot with—	
	Fox sandy loam	Nappanee silt loam
	Grams	*Grams*
Untreated	0.8	10.8
0.5 inch of sawdust mulch	.0	10.1
1 percent sawdust mixed with soil	.0	.7
2 percent sawdust mixed with soil	.0	.0
Cow manure with straw bedding [1]	10.4	11.5
Cow manure with sawdust bedding [1]	7.5	16.4
Cow manure with straw bedding [1] and phosphate [2]	10.3	11.3
Cow manure with sawdust bedding [1] and phosphate [2]	9.5	14.3

[1] Mixture used at a rate of 40 tons an acre.
[2] Phosphate used at a rate of 400 pounds P_2O_5 an acre.

Composts

Sawdust may be composted if desired. Usually this is not an economical process except where compost is especially needed in the greenhouse, or for the growing of special crops such as small fruit, vegetables, and flowers. The composting of sawdust presents no special problems except that the material decomposes a little more slowly than most plant substances that are used in compost heaps. For this reason it is well to compost sawdust in liberal mixture with farm manure, legume waste, succulent green material, or similar residue that is comparatively high in nitrogen. Usually some chemical nitrogen, and in all cases a little ground limestone and phosphate, should be added. A suggested formula, based on dry weights, is as follows:

Material:	*Quantity to be used (pounds)*
Sawdust	500
Spoiled hay and similar materials	300
Farmyard manure	200
Ammonium nitrate	25 to 35
Superphosphate	20 to 30
Dolomitic limestone	30 to 40

The composting process should be allowed to continue for several months under conditions of adequate moisture before the material is used.

Direct Application to Soil

The direct application of sawdust to field soils is entirely feasible provided sufficient available nitrogen is added to bring the nitrogen content of the sawdust up to about 1.2 to 1.5 percent, assuming that no nitrogen is lost by leaching. As already stated, this corresponds to 115 pounds of ammonium sulfate or 72 pounds of ammonium nitrate per ton of dry sawdust; or 0.8 and 0.5 pound, respectively, per bushel of loose material (see table 7). The nitrogen should preferably be supplied in two or more applications to be certain that it is there as needed. If crops such as corn or small grains are grown on the field subsequent to addition of the sawdust, the time of application and quantity of nitrogen to be added can be judged fairly well by observing the color of the foliage. Any yellowing or unexpected lag in growth is likely to be an indication that nitrogen is needed. If acidity is a factor, a small amount of ground limestone should be applied with the sawdust. It is also advisable to apply the sawdust several weeks before planting the crop if this can be done. This will help to avoid any direct or indirect toxic effects, such as discussed earlier. Application in the early fall after harvesting a crop, followed by addition of nitrogen in the spring, is one practical method of using sawdust without interfering with the usual crop rotation. Addition to sod crops, together with adequate nitrogen, is another practical method and there is little likelihood of injury. In the small home garden sawdust may be added to the soil surface and spaded under, as shown in figure 4.

Sawdust may also be applied prior to the seeding of a well-inoculated legume crop. During the seedling stage some combined nitrogen is needed to insure the formation of nodules and their function-

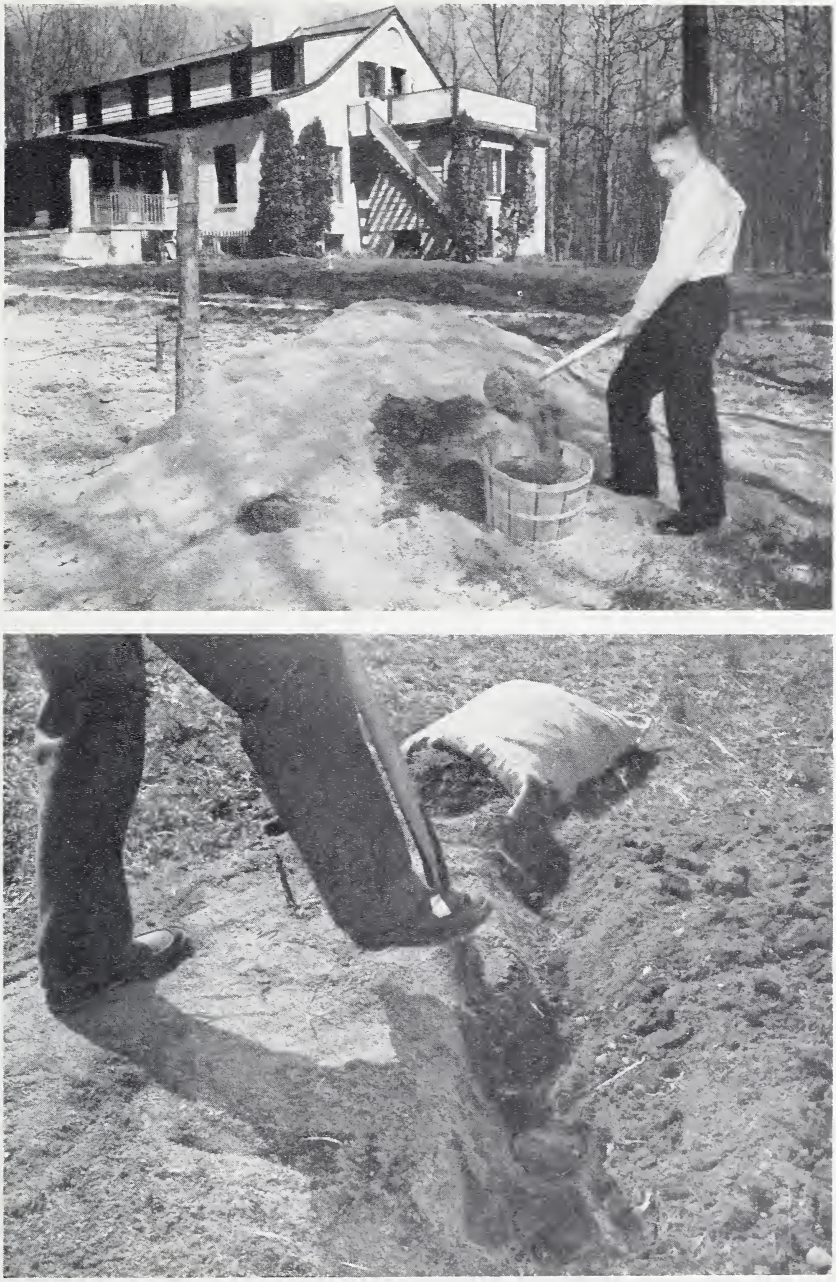

FIGURE 4.—Sawdust improves the physical condition of a heavy-textured soil: Top, a sawdust storage pile of about 2 cubic yards, a size sufficient for a small home garden; below, spading sawdust into the soil.

ing; but later, if soil nitrogen should become deficient, the legume will meet its requirements from the air. This may reduce somewhat the need for chemical nitrogen. Turk (*24*) conducted experiments of this type. He obtained some decrease in the growth of soybeans where 1 or 2 percent sawdust was applied but, unfortunately, no lime was added to the acid soil used, and nodulation of the plants was poor. In similar tests where lime was applied, 1 percent of sawdust did not decrease the growth of either well-inoculated red clover or alfalfa. Viljoen and Fred (*26*) also found that inoculated red clover grew about as well in the presence of 1.5 to 3.0 percent of four kinds of sawdust as without sawdust. There is only limited information on this method of utilizing sawdust, but there is every reason to believe that it is a good method that can be utilized to advantage under many conditions.

GENERAL RECOMMENDATIONS

Sawdust and other natural wood wastes contain comparatively small quantities of the usual fertilizer nutrients but nevertheless constitute valuable sources of organic matter for use in soil improvement. They should be utilized to an economically feasible extent. They may be used as mulches, bedding materials, or in composts, or they may be applied directly to the soil. Regardless of the use made of them, they should receive supplemental additions of nitrogen adequate to bring the total nitrogen content of the sawdust up to approximately 1.2 to 1.5 percent. This usually requires the addition of about 24 pounds of nitrogen per ton of fresh sawdust. The quantities of several different nitrogen-containing materials needed to supply the 24 pounds of nitrogen, and their approximate retail costs in Washington, D. C., in 1951, are given in table 7. The cheapest source of nitrogen is either ammonium sulfate or ammonium nitrate. Urea is also satisfactory but is less likely to be sold in local stores and may be somewhat higher in price. It is not economical to use a complete fertilizer to supply all of the nitrogen, but it is a good practice to use a high-nitrogen fertilizer, such as 10–6–4, to supply up to a third of the nitrogen needed. This would also provide adequate available phosphorus. As already pointed out, sawdust tends to deplete available phosphorus just as it does nitrogen, but the effect is less evident.

The required nitrogen should be applied in at least two, and preferably more, applications during the season so as to make certain that it is present when needed. If applied in a single application much of the nitrogen may either be leached away or, if a crop is present, may be assimilated by the crop, leaving little to feed the decay microorganisms. Most of the added nitrogen that contributes to humus formation will, of course, not be available for crop use during the first growing season, and hence additional quantities should be added if it is desired to feed the crop as well as the micro-organisms.

Sawdust has little effect on soil acidity, but it is nevertheless desirable to apply 100 pounds or more of finely ground limestone per ton of dry material unless the sawdust is to be used on acid-requiring crops or it is known that the soil is already well supplied with basic materials. Sawdust may be used at almost any rate of application, but since the quantity of nitrogen required is high there are good practical reasons for limiting the rate of individual application.

TABLE 7.—*Approximate quantity and retail costs*[1] *of various nitrogen sources required to counteract the nitrogen-depleting effect of a ton of average fresh, dry sawdust*

Nitrogen source	Nitrogen content	Quantity required[2]	Retail cost[2]
	Percent	*Pounds*	*Dollars*
Ammonium sulfate	21. 0	115	4. 25
Ammonium nitrate	33. 5	72	4. 55
Sodium nitrate	16. 0	150	6. 00
10–6–4 fertilizer	10. 0	240	8. 15
5–10–5 fertilizer	5. 0	480	12. 50

[1] In Washington, D. C., 1951.
[2] The quantities needed for a bushel of sawdust and the cost may be obtained by dividing these values by 150.

As certain kinds of sawdust occasionally contain small quantities of materials that retard plant growth, it is advisable to use weathered material or to apply unweathered material 2 or more months prior to planting. This period should be even longer if the sawdust is to be applied during the cold months when biological activities are extremely limited.

Sometimes sawdust that has decayed for several years, without mineral additions, is available for use by the grower. Such material usually serves as a satisfactory mulch but due to its low content of plant nutrients, especially nitrogen, it will not produce the same beneficial effects on plant growth as well-rotted manure or compost. Chemical fertilizers are needed to serve as a supplement.

In this circular an attempt has been made to discuss the main factors involved in the proper use of sawdust in agriculture. Although sawdust sources may be nearby there are many factors of economics, especially cost of labor and of nitrogen, that determine whether or not a grower can profitably use the material. For example, in a livestock system of farming, it may be more feasible to maintain organic matter primarily by the use of a large proportion of sod crops in rotation, supplemented by manures. Sawdust can provide bedding material, however. Furthermore, some soils are not especially in need of further additions of organic matter. If such soils are deficient in nitrogen it probably would be more profitable to supply the element directly to the crop rather than indirectly through soil organic matter. Direct applications bring more immediate responses from the added fertilizer and there is usually less loss of nitrogen through leaching and gaseous diffusion.

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